Assessing Chemical Exposures during Military Deployments

Guarantor: Veronique D. Hauschild, MPH
Contributors: Veronique D. Hauschild, MPH; LTC Arthur P. Lee, MS USA (Ret.)

Before the first Persian Gulf War, military chemical concerns were focused on life-threatening/performance-impairing effects from exposures to chemical warfare agents. Now, hazards of concern include both high and low levels of chemical warfare agents and toxic industrial chemicals in air, soil, and water. The types of health effects considered have expanded to include both immediate, acute effects (mild and severe), and delayed or chronic outcomes. Because federal exposure standards are not applicable to deployed personnel, the U.S. Army Center for Health Promotion and Preventive Medicine established military-specific exposure guidelines in Technical Guide 230, *Chemical Exposure Guidelines for Deployed Military Personnel.* Methods used to develop the guidelines address toxicological data limitations, uniqueness of military populations and exposure scenarios, and a risk assessment process compatible with existing military operational risk management doctrine. The Technical Guide 230 helps ensure chemical hazards are addressed in various deployment scenarios.

Introduction

Military personnel may be exposed to many environmental chemical hazards during deployments. The intentional use of chemical warfare agents (CWA) or the intentional or accidental release of toxic industrial chemicals (TICs) may expose personnel to localized high levels of toxic exposures as well as residual low-level exposures. Other exposures may result from inhalation of ambient contaminants caused by poor environmental controls at deployment sites, burning of propellants, trash, and human waste, bulk-fueling operations, pesticide spraying, or many other scenarios. Adverse health effects can also be associated with chemicals in drinking water or from contact with contaminated soil. Whereas the extent of the health effects caused by such exposures are not always entirely clear, the results may range from significant immediate effects that impact mission performance to delayed health effects that affect postdeployment quality of life. These risks from environmental chemical exposures must be assessed and integrated into overall military operational risk management (ORM).

Background

Since the mid-1990s, concerns have been raised regarding the adequacy of the Department of Defense (DoD) doctrine and technology to identify and defend troops against the possible adverse effects of low-level CWA exposure. Several reports[1-4] have also pointed to TICs that may be implicated in potential health outcomes. In 1998, the Government Accounting Office concluded that the DoD had not developed doctrine that addressed low-level exposures to chemical agents either in isolation or in combination with other contaminants found on the battlefield.[5]

The DoD has initiated research and policies[6-9] to identify the cause (environmental exposures) and effect (medical outcome) relationships associated with various chemicals. For several years now, the services have been collecting air, water, and soil samples to characterize the environmental exposures occurring during military operations.[10-13] These environmental samples have been analyzed for military unique CWAs and TICs. The initial assessments of the samples were hindered by the lack of pre-established military exposure guidelines (MEGs) or standards applicable to deployments. Federal guidelines and standards (e.g., Occupational Safety and Health Administration and the Environmental Protection Agency [EPA]) are more applicable to protect workers and the civilian public for lifetime exposures.

To address this issue, scientists at the U.S. Army Center for Health Promotion and Preventive Medicine developed Technical Guide (TG) 230, *Chemical Exposure Guidelines for Deployed Military Personnel,*[14] which provides ranges of concentration levels associated with varying degrees of effect severity. Guidelines are provided for short-term exposures (from 1 hour to 14 days) and long-term exposures (up to 1 year). TG 230 uses military ORM terminology to describe the significance of the severity levels and health effects. It also defines low level as exposures to concentrations over specified durations that would not cause immediate acute or severe health effects. Low-level exposures may result in mild or possibly delayed health effects but are not expected to cause adverse operational impacts. TG 230 is intended to be a consolidated reference tool for military preventive medicine personnel to provide expedient risk management decisions to a commander during deployments.

Methods

Existing toxicological data and risk assessment methodologies, including published health standards and guidelines, were the basis for developing the guidelines in TG 230. This process took advantage of national and international expertise used to evaluate the basic toxicological data and provided the broadest array of information for the most chemicals. Four issues had to be addressed in developing these guidelines:

- toxicological data limitations,
- military population of concern,
- deployment scenarios and exposure durations, and
- balancing operational risks and compatibility with existing military ORM guidance

Toxicological Data Limitations

Specific concerns relative to the military's ability to assess CWAs have highlighted toxicological data gaps and scientific

Deployment Environmental Surveillance Program, U.S. Army Center for Health Promotion and Preventive Medicine, 5158 Blackhawk Road, Aberdeen Proving Ground, MD 21010.

This manuscript was received for review in January 2003. The revised manuscript was accepted for publication in May 2003.

uncertainties. For example, the previously cited Government Accounting Office report refers to the "imprecise and unpredictable" procedure of extrapolating animal data to human exposure levels, different routes of exposure, and the lack of information on combined exposures. However, these same uncertainties exist for most TICs, and this has not prevented the EPA or Occupational Safety and Health Administration from establishing exposure guidelines and standards for the civilian population. The scientists at U.S. Army Center for Health Promotion and Preventive Medicine chose to use existing data and standard risk assessment models that these agencies used to develop their standards and guidelines. Some existing guidelines were also used with only minor adjustments. No additional toxicological studies were performed to produce the guidelines presented in TG 230. Assessments performed by non-DoD health agencies were used as the primary basis for these MEGs. When new data or models become available, this new information will be incorporated into future updates of TG 230.

Military Populations

Military personnel have historically been considered more physically fit than the general civilian population. However, the current deployed U.S. military encompasses a diverse population and may be similar to the general civilian population.[15] Current military demographics indicate that military personnel are older than previous generations, and the Services have more women and a broader range of ethnicities.[3,16] This diversity includes those with certain medical conditions (such as nonacute asthmatics) and many genetic subgroups (such as those with abnormally low acetylcholinesterase activity) that are expected to have greater susceptibility to certain chemical hazards.[15] The potential impact of deployment-related stresses such as fatigue, climate extremes, poor nutrition, and mental stress cannot be discounted. The level of physical fitness of these individuals should not be considered a reason to assume that they are less susceptible to illness from chemical exposures than average members of the adult civilian population. Because of these similarities, similar health effects data, risk models, and guidelines established for the general civilian population were used to assess health risks to the military. Standards designed specifically to protect children were not used.

Military Exposure Scenarios and Durations

Whereas the military demographics and susceptibilities may be similar to the general population, the exposure scenarios are different, such as greater inhalation rates and water ingestion rates. For example, the consumption rates of water for deployed troops is assumed to be 5 to 15 L a day, which is greater than the average U.S. adult consumption rate of 2 L per day. The exposure duration is also unique for military situations. Generally, individual military personnel are not deployed longer than a year at a time, and actual exposure scenarios may be only for brief, one-time excursions. In contrast, the EPA-based risk assessment[17] and occupational exposure models[18] assume continuous repeated daily exposures over a lifetime (30–70 years).

Specific military relevant duration periods were defined for the guideline concentrations represented in TG 230 as:

- Temporary exposures (minutes–24 hours of exposure): This is relevant when assessing inhalation of airborne vapors or particulate matter. Guidelines for TICs are provided as single 1-hour and 8-hour time periods. For CWAs, additional guidelines for 10- to 30-minute and 8-hour exposures are provided.
- Short-term exposures (1–14 days of exposure): For air, this refers to continuous daily exposures; for drinking water, short-term exposure durations are expressed in terms of 1 to 5 days or up to 14 days.
- Long-term exposures (15 days to 1 year of exposure): Long-term exposure guidelines are derived from subchronic or chronic toxicity reference values for air, water, and soil and can be used as screening levels to prioritize those areas that need further assessment. When sample results are below these long-term guidelines, no adverse health effects (immediate or delayed) are anticipated even for continuous long-term exposure.

Balancing Operational Risks

FM 100-14, Risk Management, states that "Both military leaders and their staffs manage risks. Staff members continuously look for hazards associated with their areas of expertise. They then recommend controls to reduce those risks. . . . Leaders should advise the chain of command on risks and risk reduction measures."[19]

In establishing military chemical exposure guidance, it was important to realize that attempting to protect military forces to "no adverse health effects" levels may, in some scenarios, have unintended adverse consequences. For example, the donning of chemical protective clothing can result in heat stress, dehydration, and diminished capacity to effectively accomplish certain tasks. Avoidance of a chemical exposure may lead one to choose alternative routes or locations in which there are logistical and physical hazards that may pose greater risk to personnel and the mission. Therefore, it is necessary to ensure that risks from chemicals are appropriately balanced with the risks from other deployment hazards.

Existing military ORM doctrine establishes the process that the military assesses and balances various types of risks. The FM 100-14 ORM Risk Assessment Matrix tool is presented in Table I. Risk from chemical exposure risks must be presented in this fashion to allow the commander to compare different risks in the battlespace (i.e., those risk posed by logistical limitations, enemy attack, as well as chemical exposure) using a common scale and definitions.

TABLE I

MILITARY RISK ASSESSMENT MATRIX

	Probability				
Severity	Frequent	Likely	Occasional	Seldom	Unlikely
Catastrophic	E	E	H	H	M
Critical	E	H	H	M	L
Marginal	H	M	M	L	L
Negligible	M	L	L	L	L

E, Extremely high risk; H, high risk; M, moderate risk; L, low risk.

Results

The following sections summarize the types of MEGs and the application guidance that are provided in TG 230.

MEGs for Air

Although not all-inclusive, 14 military unique compounds (CWA, smokes/obscurants, riot control agents) and more than a hundred common industrial chemicals are listed in TG 230 with associated air MEGs. Ongoing evaluations of worldwide chemical production data and associated toxicity information continue to identify additional chemical hazards faced by deployed forces. These chemicals will be added to the TG 230 as it is updated.

The concentration values (presented in milligrams per cubic meter or mg/m^3) that serve as the basis for the air MEGs were derived from various sources including the National Research Council,[20,21] the American Industrial Hygiene Association,[22] the American Conference of Governmental Industrial Hygienists,[18] the Agency for Toxic Substances and Disease Registry,[23] the U.S. Environmental Protection Agency,[19] and other organizations. The specific hierarchy of existing guidelines and standards used to establish the various temporary, short-term, and long-term air MEGs is described in the Reference Document 230[15] associated with TG 230. Examples of key criteria include the acute exposure guidelines levels[20] and emergency response planning guidelines[22] for temporary and short-term MEGs, adjusted 8-hour time-weighted average threshold limit values[18] for short-term and long-term MEGs, and EPA-modeled reference concentrations for long-term MEGs. Some of the guidelines were adjusted to better reflect the military exposure scenario and also to accommodate a specifically derived military inhalation rate. As a result, the overall ranges of MEGs are similar to some of the existing federal standards and guidelines. Figure 1 depicts a general schematic of how some of the air MEGs relate to common occupational and general population standards.

MEGs for Drinking Water

Drinking water MEGs were developed for more than a hundred chemicals including certain military-unique compounds as well as common industrial/agricultural chemicals that are considered likely or probable water source contaminants. As additional chemicals are identified as potential threats to deployed forces, they will be added to TG 230 in future updates. The key sources used to formulate the drinking water MEGs include existing military standards in field drinking water doctrine (Technical Bulletin-Medical 577),[24] adjusted EPA health advisories, and Agency for Toxic Substances and Disease Registry minimum risk levels. These were adjusted to suit military short-term and long-term military exposure durations. Guideline levels were also adjusted to reflect the high consumption rates expected in deployment settings (5–15 L a day versus the average U.S. adult consumption rate of 2 L per day). As a result of these extremely high-consumption rates, some drinking water MEGs are lower than corresponding EPA guidelines.

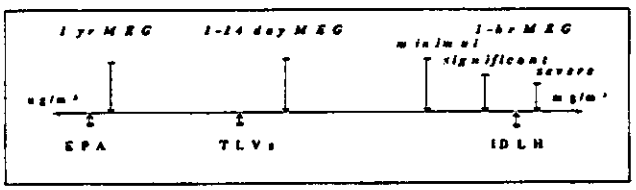

Fig. 1. Conceptual view of air MEGs relative to existing standards.

MEGs for Soil

Soil MEGs were developed for more than a hundred commonly detected or anticipated soil constituents/contaminants. The list will be expanded as new concerns are identified and data become available. Although soil exposures can be significant during deployments, they can be mitigated through clothing barriers, washing, and dust control measures. Irritation or odor would immediately encourage personnel to use these controls, therefore, short-term or acute MEGs were not deemed necessary for soil. Because some level of continuous exposure to soils will occur during a deployment, long-term, low-level MEGs were developed. These soil MEGs are based on EPA health risk assessment models[17] and incorporate specific exposure parameters into the model that reflect typical deployed military activities.

Example MEGs and Application

In addition to providing the MEG values, TG 230 provides guidance and example scenarios to demonstrate how to use the information in standard military risk management terms. Several different deployment scenarios from wartime to peacekeeping support operations are presented. These example scenarios do not establish the only way risk decisions can be made but address the different parameters that should be considered when evaluating chemical exposure health risks.

One example scenario is a reconnaissance team establishing a site for a future base camp. Benzene was detected at concentrations averaging 5 mg/m^3 in several air samples around a factory being considered for temporary living quarters. Table II summarizes the information relative to health effects and MEGs for benzene air exposures available in TG 230. The following paragraphs describe the ORM risk characterization process.

Determine Hazard Probability

In this example, the benzene concentrations are below the 1-hour MEGs so one can assume there is not an immediate or severe health hazard. However, the concentrations exceed the 1-year, the 1- to 14-day, and the 8-hour MEGs. One may assume that in this scenario service members may be exposed for a long duration and quite frequently if used as housing quarters. It is also likely that these personnel would not notice that they were being exposed and thus not try to avoid exposure because the concentrations are below odor thresholds. As a result, the probability of exposure at or above these MEGs can be categorized as "frequent" on the probability scale in Table I.

Determine Hazard Severity

The significance of exceeding these MEGs is based on the levels of health effect severity and medical impact as summarized by Table III. In comparison to the hazards severity definitions in Table III, the health effects from benzene exposures described in Table II can be categorized as "negligible" severity (mild and of minimal operational impact) at the measured concentrations.

TABLE II

BENZENE MEGS FOR AIR

MEG values (mg/m^3)					
1-hour MEGs			8-hour MEG	1- to 14-Day MEG	1-Year MEG
Severe effects level	Significant effects level	Minimal effects level	Minimal to no effects level	Minimal to no effects level	No effects level
3,195	479	160	1.6	0.16	0.039

Benzene, CAS No. 71-43-2. Health effects: Irritation to eyes, skin, nose, respiratory tract; headache, fatigue, loss of appetite, lassitude; known carcinogen; chronic exposures to low levels cause bone marrow depression. Odor: aromatic, at ranges of 108–380 mg/m^3.

TABLE III

ORM HAZARD SEVERITY DEFINITIONS IN TERM OF HEALTH EFFECTS AND MEDICAL TREATMENT LEVELS

Hazard Severity	Health Impacts Associated with Hazard Severity Level
Catastrophic	Many deaths and severe disabling/incapacitating casualties requiring significant medical attention (e.g., echelon IV) and/or additional personnel support for survival.
Critical	Few if any deaths, but significant numbers of disabling/incapacitating casualties, many requiring medical treatment or support (e.g., minimum echelon III, possibly echelon IV); others are likely to have noticeable but not disabling health effects.
Marginal	Many persons may have noticeable but not disabling health effects and/or the potential for individuals to have delayed (postmission or deployment) health effects is considered very possible. The acute (observable) effects require minimal medical attention but may enhance stress-related casualties.
Negligible	Few if any persons expected to have noticeable health effects. The potential for individuals to have delayed (postconflict) health concerns is considered minimal to none.

Determine Risk Estimate and Confidence

The risk estimate is determined by combining the hazard severity and hazard probability using the risk assessment matrix in Table I. In this example, a "negligible" severity and a "frequent" probability results in "moderate" risk. The confidence associated with this estimate is determined based on the quality of the field/sample data, site-specific exposure information, and toxicity data. The confidence was low in this case because the air samples were only taken once on a single day. A summary of the information that could be presented to a commander relative to this assessment is presented in Table IV.

Implications

Identification and assessment of health risks associated with chemical exposure is clearly an important requirement in today's deployment operations. However, it is not an exact science and requires professional judgment. The use of TG 230 requires a basic understanding of toxicological and industrial hygiene concepts that are taught to preventive medicine officers at the U.S. Army Medical Department Center and School. ORM training using TG 230 is also incorporated into the curriculum. The information provided in TG

TABLE IV

EXAMPLE CHEMICAL RISK ASSESSMENT SUMMARY TABLE

	Hazard Ranking		Operational Risk Estimate		Potential Impacts		
Chemical Hazard	Hazard Probability	Hazard Severity	Risk Level	Confidence	Health	Operational	Courses of Action (COA) and Notes
Benzene in air	Frequent	Negligible	Moderate	Low	Potential symptoms: immediate irritation to eyes/nose/respiratory tract; headaches, fatigue. Delayed, dermatitis, bone marrow depression, cancer Target organs/systems: eyes, skin, respiratory system, blood, central nervous system. Estimated incidence, probably <10%	Even short-term exposure (day to weeks) could lead to increased sick call for minor illnesses, fatigue, morale impacts. Slight degradation of personnel functional capabilities/attention to detail possible. Exposed personnel at increased risk for future health impacts—documentation and future medical surveillance required.	Option 1: accept risk (allow exposure) and 1a, document exposure in personnel records (required); 1b, conduct additional monitoring to better assess exposure fluctuations (optional). Option 2: minimize risk 2a, avoid exposure by choosing alternate housing accommodations; 2b, mitigate exposures by identifying source and providing source controls.

230 will allow the medical staff to provide relevant information to commanders about chemical risks.

The ability to communicate information about the health effects and risks to various audiences (exposed personnel, commanders, and even the public) is very important. It is critical that medical (i.e., clinical) personnel and preventive medicine personnel coordinate to determine if chemical exposure assessments and actual unit health status or medical complaints parallel one another. Even in cases where chemical exposures only result in potential risk of delayed effects, clinical personnel should be aware that these exposures must be documented in archives[9] that can be used to evaluate individual exposures many years in the future.

Future Efforts

The National Research Council Committee on Toxicology is currently reviewing TG 230. The U.S. Army Center for Health Promotion and Preventive Medicine will use the National Research Council's comments and recommendations to improve the guidance in future updates of TG 230. The information on various chemicals and MEGs is also being used in the development of chemical detectors and protective equipment.

The TG 230 is a reference that has many applications. It will continue to evolve to address new science, chemicals, policies, and political concerns and provide a basis from which personnel can address chemical exposure concerns during deployments.

Acknowledgments

This presentation summarizes the work of the U.S. Army Center for Health Promotion and Preventive Medicine and those individuals contributing to TG 230 and its reference document (RD 230). Special attribution is given to Ms. Joleen Johnson for efforts to assist further advancement of this work.

References

1. Institute of Medicine: Report on Interactions of Drugs, Biologics, and Chemicals in U.S. Military Forces. Washington, DC, National Academic Press 1996.
2. House of Representatives: Bill HR 4036, Persian Gulf War Veterans Health Act of 1998.
3. Institute of Medicine: Health Consequences of Service during the Persian Gulf War, Recommendations for Research and Information Systems. Washington, DC, National Academic Press 1996.
4. Authorization Conference Language, House Report 105-736, Bill Language: Section 247. Chemical Warfare Defense, 1998.
5. Report to Congressional Requesters: Chemical Weapons: DoD Does Not Have a Strategy to Address Low-Level Exposures. Washington, DC, U.S. General Accounting Office, September 1998.
6. Annual Report to Congress: Federal Sponsored Research on Gulf War Illness. Washington, DC, Department of Veteran Affairs, March 1998.
7. DoD Directive 6490.2, Joint Medical Surveillance, August 30, 1997.
8. DoD Directive 6490.3, Implementation and Application of Joint Medical Surveillance for Deployments, August 7, 1997.
9. Joint Chiefs of Staff Memorandum: Updated Procedures for Deployment Medical Surveillance. Washington, DC, Joint Chiefs of Staff, February 2002.
10. U.S. Army Environmental Hygiene Agency, Final Report, Kuwait Oil Well Fire Health Risk Assessment, May 5-December 3, 1991, Report Number 39-26-L192-91, Aberdeen Proving Ground, MD, USAEHA, February 18, 1994.
11. U.S. Army Center for Health Promotion and Preventive Medicine, Results of Soil Samples, Operation Southern Watch 1998, USACHPPM Project Number 47-EM-8111-98, Aberdeen Proving Ground, MD 21009, USACHPPM, March 31, 1998.
12. U.S. Army Center for Health Promotion and Preventive Medicine, Final Human Health Risk Assessment, Eskan Village, Saudi Arabia, USACHPPM Project Number 39-EJ-7076-98, Aberdeen Proving Ground, MD, USACHPPM, April 3, 1998.
13. U.S. Army Center for Health Promotion and Preventive Medicine, Environmental Sampling Assessment of the Proposed U.S. Army Forces Central Command Kuwait (ARCENT-KU) Facility, April 24–May 14, 1998, Environmental Surveillance Assessment Number 47-EM-4150-98, Aberdeen Proving Ground, MD, USACHPPM, January 23, 1999.
14. U.S. Army Center for Health Promotion and Preventive Medicine: Technical guide 230: chemical exposure guidelines for deployed military personnel. MCHB-TS-RDE, APG-EA MD. April 2002.
15. U.S. Army Center for Health Promotion and Preventive Medicine: Reference document: a companion document for USACHPPM TG 230. MCHB-TS-RDE, APG-EA MD. January 2002.
16. National Research Council: Strategies to Protect the Health of Deployed U.S. Forces. Analytical Framework for Assessing Risks. Washington, DC, National Academy Press, 2000.
17. U.S. Environmental Protection Agency: Region IX Preliminary Remediation Goals. San Francisco, CA, U.S. Environmental Protection Agency Region IX, May 1, 1998. Available at http://www.epa.gov/region09/waste/sfund/prg/intro.htm; accessed 1989.
18. American Conference of Governmental Industrial Hygienists: Threshold Limit Values for Chemical Substances and Physical Agents, Ed 2. Cincinnati, OH, American Conference of Governmental Industrial Hygienists, 1996.
19. Field Manual 100-14, Risk Management. Washington, DC, Headquarters Department of the Army, April 23, 1998.
20. National Research Council, Committee on Toxicology: Standing Operating Procedures for Developing Acute Exposure Guideline Levels for Hazardous Chemicals. Subcommittee on Acute Exposure Guideline Levels, Committee on Toxicology, National Research Council. Washington, DC, National Academy Press, 2001.
21. National Research Council, Committee on Toxicology: Criteria and Methods for Preparing Emergency Exposure Guidance Level, Short-Term Public Emergency Guidance Level, and Continuous Exposure Guidance Level Documents. Washington, DC, National Academy Press, 1986.
22. American Industrial Hygiene Association: Emergency Response Planning Guidelines and Workplace Environmental Exposure Level Guides Handbook. Fairfax, VA, American Industrial Hygiene Association Press, 1997.
23. Agency for Toxic Substances and Disease Registry: Toxicological Profiles on CD-ROM. Boca Raton, FL, CRC Press, 1997.
24. Department of the Army: Sanitary Control and Surveillance of Field Water Supplies (DRAFT). Technical Bulletin, Medical 577, USACHPPM, APG-EA, MD, 1999.